HOW TO IMPROVE THE AGRONOMIC EFFICIENCY IN PRECISION MAIZE PRODUCTION

Pepó Peter*, FeketeÁgnes*, Vad Attila **

*University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, H-4032 Debrecen, Böszörményi str. 138., Hungary
e-mail: pepopeter@agr.unideb.hu
e-mail: fekete.agnes@agr.unideb.hu
**University of Debrecen, Institutes for Agricultural Research and Educational Farm, H-4032 Debrecen, Böszörményi str. 138., Hungary
e-mail: vadattila@agr.unideb.hu

Abstract

Nowadays the most important challenge is in crop production how to reduce the huge industrial inputs and how to improve the agronomic efficiency of technology. The one of the best way is to use the agrotechnical elements of precision technology. The effects of different crop management factors were studied in long-term experiments on chernozem soil in Eastern Hungary (Debrecen). In sustainable maize production the fertilization resulted high yield surpluses in average (2.0-4.1 t ha^{-1}) and rainy (2.1-5.4 t ha^{-1}) crop year (LTE2). Our scientific results proved that the modern maize genotypes had high maximum yields (15.4-16.6 t ha^{-1}). The maximum yield of maize hybrids depended on fertilizer doses and plant density. We founded a special interaction between fertilization and plant density: in higher plant density we had to use higher dose of fertilizer (LTE1). In N_{opt} +PK treatment we obtained higher WUE values (36.6-46.9 kg ha^{-1}) comparing with control treatment (28.7-33.6 kg ha^{-1}) in maize production.

Key words: maize, agrotechnical elements, genotypes, water use efficiency (WUE)

INTRODUCTION

Significant yield increases of cereals (mainly wheat and maize) have been achieved from the 1970's years in the developed and partly in the developing countries. These yield increasements were based on the huge industrial, chemical inputs (fertilizers, pesticides, gasoline etc.) and new genotypes of cereals. This "industry-like" crop production resulted high yield and enormous harmful environmental effects and less agronomy and energy efficiency (Austin 1999, Pepó 2007, Olesen et al. 2011). Traditional cereal production uses a lot of external inputs to achieve high yields (Hole et al. 2005). Hungarian crop production is cereal-oriented one. Proportion of cereals (small grains and maize) takes about 70% of Hungarian arable land. In sustainable cereal production nutrient supply, fertilization is a key agrotechnical element (Jordan et al. 1997, *Oehl* et al. 2004, Keller et al. 2012), but the crop rotation, irrigation, plant density, weed control (Berzsenyi et al. 2000, *Vad* et al. 2007) have important role, too. The yield-losses and yield fluctuation of cereals caused by crop year (climate change) depended on soil conditions, the stress-tolerance of genotypes and the agrotechniques. According to literature (*Shen* et al. 1999, *Pepó* 2009) the yield decreases of cereals varied between 2-55%. Because of climate change the water saving crop management and water use efficiency are especially important in arable crop production.

Precision maize production is an integrated crop management system that combines information technologies with rational agricultural methods and attempts to provide amount and type of inputs based on actual need of cultivation. Precision crop production can be a cost saving technology and it has many environmental benefits (*Doberman* et al. 2004, *Breazeale* 2006, *Krishnan* et al. 2006, *Hosseini* et al. 2010).

The main aim of this study was to evaluate the long-term experimental data on chernozem soil in Eastern-Hungary to show the effects of ecological factors and agrotechnical elements and genotypes on the yields of maize.

MATERIAL AND METHOD

Our study was based on long-term experiments on chernozem soil in Eastern Hungary.

The long-term experiments were set up in Látókép Experimental Station on calcorouschernozem soil in 1983 year. Geographical location is N 47°33' and E 21°27'.

Soil type is chernozem which has nearly neutral pH (pH_{KCl} = 6.46). The original chemical traits of soil are as the following: humus content 2.76% (0-0.2 m upper soil layer), thickness of humus layer 0.8 m, AL-P_2O_5 content 130 mg kg^{-1}, AL-K_2O content 240 mg kg^{-1} of plowing layer). Chernozem soil has excellent water husbandry.

The long-term experimental site can be characterized by continental climatic conditions. The average yearly precipitation is 565 mm and average yearly mean temperature is 9.84 °C.

Fertilizer response testing of maize genotypes experiment which includes 2 factors (i = fertilization, control and N = 30 kg ha^{-1}, P_2O_5 = 22.5 kg ha^{-1}, K_2O = 26.5 kg ha^{-1} and 2-, 3-, 4-, 5-folds of the basic dose; ii = genotypes [4 hybrids]). The experimental design is split-split-plot with 4 replications. The plot-size is 10 m^2. (Long-term experiment 1 = LTE1)

Polyfactorial long-term experiment of cereal crop models which includes 3 factors (i = crop rotation: mono-, bi- and triculture, ii = fertilization: control and N = 60 kg ha^{-1}, P_2O_5 = 45 kg ha^{-1}, K_2O = 45 kg ha^{-1} and 2, 3, 4-folds, iii = water supply [rainfed and irrigated]). The experimental design is split-split-plot with 4 replications. The plot-size is 46 m^2. (Long-term experiment 2 = LTE2)

The experimental data analysed with SPSS 13.0 statistical software package.

RESULTS AND DISCUSSION

Maize is a sensitive field crop to agroecological and agrotechnical factors. Our multifactorial long-term experimental data (LTE2) proved that the effects of fertilization were different depending on the crop rotation and the weather of crop year. In Eastern Hungary characterized by continental climate the precipitation quantity and its distribution are the decisive agroecological factors on chernozem soil. The effects of crop year were significant on the yields of maize in every crop rotation (*Table 1*). We obtained the strongest effect of crop year in monoculture, so sustainability needs diversified crop rotation. The efficiency of fertilization was modified by crop year and crop rotation. The yield surpluses of maize were low (891-1315 kg ha^{-1}) in dry crop years and they were much bigger in average (1998-4145 kg ha^{-1}) and in rainy crop years (2117-5399 kg ha^{-1}), respectively. The biggest fertilization effects were in monoculture and lowest ones were in triculture (*Table 1*) because of high control yields. So the appropriate crop rotation can reduce the N+PK fertilizer doses (in mono- N_{180} +PK, in bi- N_{120} +PK, in triculture N_{60} +PK) and can promote the sustainability in maize production.

Our long-term research data (LTE2) proved that the using optimum fertilizer doses (N+PK) can increase the water use efficiency (WUE = kg yield/1 mm rainfall in vegetation period) of maize both in dry and average crop years (*Table 2*). In different crop rotations the WUE of control varied between 9.5-23.7 kg mm^{-1} in dry and 20.8-30.6 kg/mm in average crop years, respectively. In optimum N+PK treatment the WUE values were much higher (15.2-28.2 kg mm^{-1} and 35.8-40.4 kg mm^{-1}, respectively).

Table 1

Effect of crop year, crop rotation and fertilization on the yield of maize in long-term experiment

(Debrecen, chernozem soil, 1986-2014)

Crop rotation	Yield (kg ha^{-1})					
	Dry crop year 11 years (38%)		Average crop year 12 years (41%)		Rainy crop year 6 years (21%)	
Monoculture						
Control	3743 e	1315*	6397 e	4145*	7190 c	5399*
N_{opt} +PK	5058 d		10 542 bc		12 589 a	
Biculture						
Control	7279 bc	924*	9289 d	2825*	9963 b	2117*
N_{opt} +PK	8203 a		12 114 a		12 080 a	
Triculture						
Control	6708 c	891*	9451 cd	1998*	10 023 b	2355*
N_{opt} +PK	7599 ab		11 449 ab		12 378 a	

*yield surplus of fertilization (kg ha^{-1})

a, b, c, d, e Letters are significantly different at $P \leq 0.05$ level

Table 2

Water use efficiency (WUE) of maize in different crop years
(Debrecen, chernozem soil, non irrigated)

Crop rotation	Fertilizer treatment	Dry crop year	Average crop year
		yield kg/1 mm rainfall in vegetation period	
Monoculture	Control	9.5 d	20.8 d
	N_{opt} +PK	15.2 c	39.1 a
Biculture	Control	22.1 b	28.4 c
	N_{opt} +PK	27.2 ab	35.8 ab
Triculture	Control	23.7 ab	30.6 bc
	N_{opt} +PK	28.2 a	40.4 a

a, b, c, d Letters are significantly different at $P \leq 0.05$ level

Table 3

Effect of crop year, crop rotation and irrigation on the yield of maize in long-term experiment
(Debrecen, chernozem soil, N_{opt} +PK, 1986-2014)

Crop rotation Water supply	Yield (kg ha^{-1})					
	Dry crop year 11 years (38%)		Average crop year 12 years (41%)		Rainy crop year 6 years (21%)	
Monoculture						
non irrigated	5039 d	4858*	10 536 d	1323*	11 662 c	-38*
irrigated	9897 b		11 859 bc		11 624 c	
Biculture						
non irrigated	8182 c	3341*	12 019 bc	1276*	11 723 bc	98*
irrigated	11 523 a		13 295 a		11 821 bc	
Triculture						
non irrigated	7619 c	3466*	11 547 c	1284*	12 071 ab	197*
irrigated	11 085 ab		12 831 ab		12 268 a	

*yield surplus of irrigation (kg ha^{-1})
a, b, c, d Letters are significantly different at $P \leq 0.05$ level

The most efficient agrotechnical element against drought is irrigation. The effect of irrigation depended on the meteorological situation of crop years (*Table 3*). During 29 years of our long-term experiment the proportion of crop years was the following: 38% dry, 41% average and 21% rainy crop year, respectively. The yield surpluses were fairly big in dry crop years to obtain good irrigation response of maize (3341-4858 kg ha^{-1}). In average and rainy crop years the yield surpluses of irrigation were very limited (1276-1323 kg ha^{-1} and -38-197 kg ha^{-1}, respectively).

In fertilizer response testing of maize genotypes long-term experiment (LTE1) results proved that we achieved very high yields, which were depending on fertilizer and plant density treatments. The yields of maize hybrids varied from 10.2 t ha^{-1} to 16.6 t ha^{-1}. The yields of control treatment (without fertilization) were 10.2-11.2 t ha^{-1} and the yields of Nopt +PK were 12.0-16.6 t ha^{-1}, respectively (*Fig. 1*). In 2017 year Armagnach and Fornad hybrids gave the highest yields, but the yields of Sushi and Loupiac were lower only by 0.3-1.2 t ha^{-1}. The hybrids needed pretty high fertilizer doses (N = 120-150 kg ha^{-1} +PK) to obtain maximum yields in 2017 cropyear characterized by nearly optimum rainfall amount and its distribution.

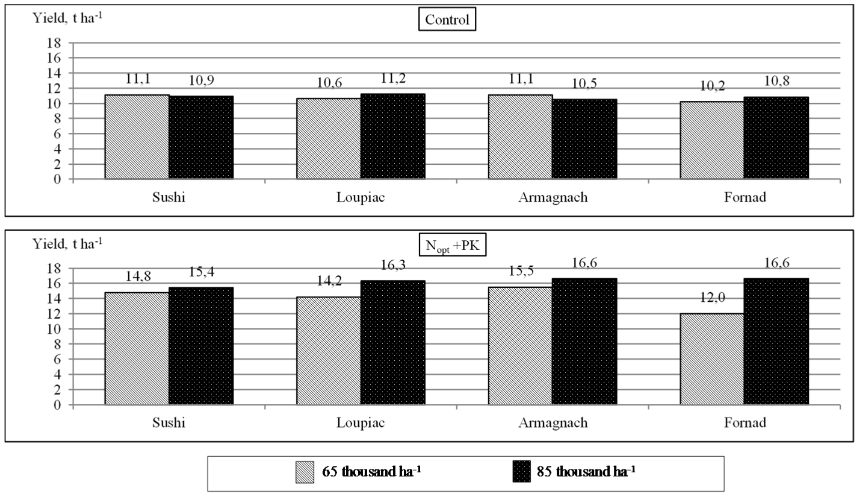

*Fig. 1:*Effect of fertilization and plant density in different maize genotypes (Debrecen, chernozem soil, 2017)

We found a special interaction between the fertilization and plant density of maize genotypes in 2017 year which had favourable water supply for maize. In low plant density (65 thousand ha^{-1}) the yield increasements of fertilization were moderate (2.9-4.4 t ha^{-1} depending on maize genotypes). In high plant density (85 thousand ha^{-1}) the maize hybrids gave very high yield surpluses by fertilization (4.5-6.5 t ha^{-1}, respectively), so in favourable cropyear we can increase the plant density of maize (*Fig. 2*).

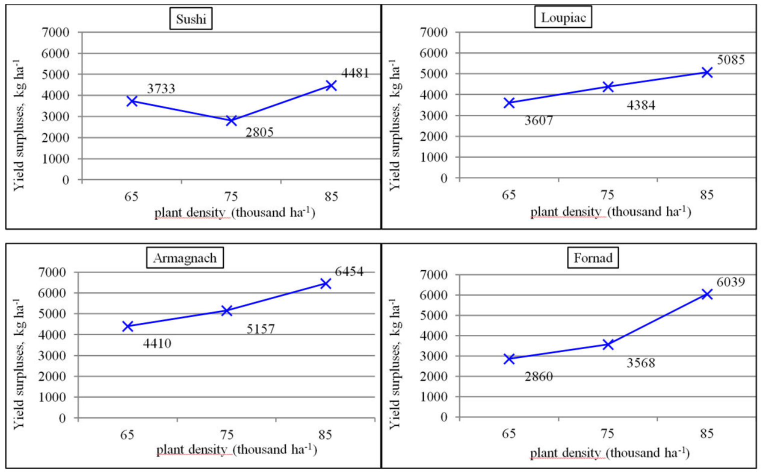

Fig. 2: The yield surpluses of maize hybrids in different plant densities (Debrecen, chernozem soil, 2017)

The optimum fertilizer doses could increase not only the maximum yield of maize hybrids, but could increase the water use efficiency (WUE), too. So the using of optimum NPK doses could improve the yield stability of maize. In control treatment the WUE values varied between 28.7-33.6 kg mm^{-1} depending on plant density and hybrids. In N_{opt} +PK treatment we obtained much higher values of WUE (36.6-46.9 kg mm^{-1}) in 2017 year (*Table 4*).

Table 4

Effect of fertilization on the water use efficiency (WUE) of different maize genotypes (Debrecen, chernozem soil, 2017)

Hybrid	Plantdensity (thousand ha^{-1})	WaterUseEfficiency (WUE) (yield/1 mm rainfall)	
		control	N_{opt} +PK
Sushi	65	31,3	41,8
	75	33,6	41,5
	85	30,8	43,4
Loupiac	65	29,9	40,0
	75	28,7	40,8
	85	31,6	45,9
Armagnach	65	31,5	43,9
	75	30,6	45,1
	85	29,6	46,7
Fornad	65	28,8	36,6
	75	30,7	40,7
	85	30,5	46,9

CONCLUSIONS

In sustainable maize production fertilization, irrigation and crop rotation have decision role on the yields. The scientific findings of *Berzsenyi* et al. (2000) and *Vad* et al. (2007) showed the crop rotation, fertilization and irrigation have main effects on the yields of maize according to our long-term experimental results.

Long-term experiments with a range of different cropping systems, fertilization treatments, genotype testing are a central component of research to develop more sustainable agricultural systems including different crop models. Monitoring agricultural sustainability requires different indicators (*Barrios* and *Sarte*, 2008).

Our long-term experimental data proved that the maize hybrids had different responses by fertilization and plant density. Russell (1991) and Duwick (2005) obtained similar results in their experiments. Under a good ecological conditions (weather in vegetation season and chernozem soil), in good agrotechnical circumstances the modern maize genotypes gave high yields. The optimum fertilizer doses were N =120-150 kg ha^{-1} +PK depending on hybrid and plant density. According with the results of *McCullogh* et al. (1994) and *Pepó* et al. (2006) we found strong interactions between the responses of fertilization and plant density in maize hybrids. Our results can be used in the development of precision maize production.

ACKNOWLEDGMENTS

The publication is supportedbythe GINOP-2.2.1-15-2016-00001 project.

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